Stereo TV Enhancement Study

SUMMARY

FINAL TECHNICAL REPORT

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STEREO TV ENHANCEMENT STUDY

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1. INTRODUCTION

1.1 STATEMENT OF PROBLEM AND PURPOSE OF PROGRAM

The purpose of the program described herein was to investigate the effectiveness of TV stereo versus non-stereo presentations with respect to the operation of a remotely controlled extra-terrestial vehicle, particular attention being paid to the problem of operating in an environment with a poor S/N ratio between noise and picture.

1.2 SUMMARY OF PREVIOUS EXPERIMENTS

A thorough literature search was conducted and a bibliography was compiled. It was discovered that numerous studies had been done comparing 2-D with 3-D in non-noisy environments. In general, there was little or no difference between the presentations. It was found that there had been numerous studies of target detection in degraded and noisy environments, but almost all of these were in 2-D. Very few studies had been performed comparing the effectiveness of a 2-D versus a 3-D presentation in a noisy environment, and the experiments that had been done suffered from some experimental design flaws.

Other studies which were consulted concerned the ability of test subjects to make size and distance judgments from photographs as well as in the real world. In general, it was discovered that judgments were seldom as good from the photographs as in the real world and that this was true regardless of the method of presenting the photographs. Additionally, many studies indicated that the accuracy of judgment was, to a large extent, a function of the structure and content of the picture, so that a picture with many familiar cues gave superior results to one with fewer familiar cues. This was true for both 2-D and 3-D.

The literature indicated that parameters such as field of view, number of TV lines, contrast, etc., had been fairly well covered. This program therefore, concentrated primarily on determining answers to the following questions:

(a) How effective is stereo versus non-stereo for judging size and distance of targets in a noisy environment?

(b) What noise levels begin to have deleterious effects, and at what noise level is the picture no longer usable? How are these levels affected by other parameters such as stereo and the subtended visual angle of the targets?

(c) What is the effect, if any, of different methods of stereo presentation?

(d) What differences are there among subjects, and how are these differences modified by training?

2. APPARATUS

The stimuli used in the Kollsman program were stereo photographs. The photographs were taken in an abandoned gravel pit to simulate the lunar surface. The targets were cones of various heights, sited at various distances from the camera. The cones were 4, 6, 10, 16, 26 and 40 inches high, and were located in pairs of various sizes at 20, 31, 50, 80, 127 and 200 feet from the camera. There were always two cones in each photograph, and the separation was 2, 3, 5, 8, 13 or 20 feet.

The cameras were mounted 41 inches above the terrain, and two inter-camera distances were used. These distances were either 4 or 12 inches. The field of view of all pictures was 60° horizontally. Seventy-two stereo pairs were used in the main body of the experiment.

Two methods of presentation were employed to present the stereo pictures to the subjects. One method used Polaroid HN 38 filters (with their axes at 90° to each other) over the projectors, the subjects wearing No. 729 Polaroid 3-D glasses. The other method of presentation used the Kollsman-developed Tri-mension Reader, in which the images were separated by mirrors and beam splitters, and presented as two separate exit pupils, one to each eye.

Noise was generated by a General Radio Company random noise generator, and projected on the screen by means of a TV projector system manufactured by the General Precision Laboratories.

The screen used in the Polaroid projection presentations was of the high-gain retroreflective type which does not depolarize the light.

3. SUBJECTS AND PROCEDURE

3.1 SUMMARY OF NUMBER AND TYPES OF SUBJECTS USED

The subjects used were engineers, technicians, and office personnel of the company. Sixty subjects were used in all, some of these being used only for preliminary exploratory experiments. In the main body of the experiment, 36 subjects were used: 8 female and 28 male. Subjects were checked to ensure that they had stereo vision, but, other than this, no visual tests were conducted.

3.2 SUMMARY OF CALIBRATION TECHNIQUES

The signal-to-noise (S/N) ration was calibrated by first measuring the picture brightness alone and then the noise brightness alone for various settings of the controls on the random noise generator and the TV projector. Brightness was measured with a Pritchard meter at 12 points over the surface of the projected picture. The brightness naturally varied from point to point and from picture to picture, but the mean value used in most cases was about 6 ft. L. as seen by the subject wearing the Polaroid glasses.

Six signal-to-noise ratios were used, defined in terms of peak-to-peak to rms value. The values were infinity (no noise), 22, 19, 16, 13 and 10 db. These values were selected on the basis of preliminary experiments and the published literature.

3.3 SUMMARY OF PRECEDURES AND EXPERIMENTAL DESIGN

In the main body of the experiment, the subjects were tested in six groups of six subjects each. Each group had a different combination of S/N ratios for a given picture, but all groups saw the same 72 pictures.

The experimental design was as follows: Twenty-four pictures were presented only to the left eye of the subject (monocular), 24 stereo presentations that were taken with the 4-inch inter-camera distance, and 24 that were taken with the 12-inch inter-camera distance. Within each group of 24 photographs, all of the six distances to targets were represented 4 times in a stratified-random method of presentation in order to avoid practice or learning effects. The same was true for the six distances between targets, and the six target sizes. Moreover, the three types of presentations (mono, 4-inch, and 12-inch inter-camera distance stereo) were also uniformly distributed throughout the entire series in order to avoid practice effects.

The S/N ratios were counterbalanced and distributed throughout the entire series so that each combination of cone-size, distance-to and distance between targets was equally represented at each noise level.

The subjects were given no information as to the actual sizes and distances involved. They were told, for scaling purposes, only the height of the camera when the photographs were made (41 inches), included horizontal visual angle (60°), and the distance from the camera to the nearest visible point at the bottom of the screen (6 feet).

Their task was to estimate the height of the two cones in each picture (in inches), the distance from the camera to the left cone (in feet), and the distance between the cones (in feet). This information was written on prepared forms which were given to the subjects at the beginning of the experiment.

The subjects were seated at various distances (2.5, 5.0, 7.5, or 10.0 feet) from the screen. Records were kept of the distance of each subject from the screen to determine if the different visual angles subtended by the screen at different distances would have any effect on the ability to judge size and distance.

For the Trimension Reader, and for the training sequences, only the best 5 subjects of the 36 subjects were used. The reason for this was that a number of the poorer subjects had such variable errors that it was felt their results would not be consistent enough to show up any differences that might exist between the two methods of presentation.

In the training sequences, the subjects were shown a number of the same slides they has been shown in the first experiment. After making their estimates again, they were then told the true values. During training, only a fraction of the total series was used, so that the subjects would not learn to recognize a particular slide and thus have perfect information of the values. After this training, they were tested on the remainder of the slides, and these results were compared with their answers on these same slides when they had first been tested.

4. RESULTS

There were consistent qualitative, as well as quantitative, differences between good and poor subjects.

The good subjects tended to overestimate small sizes and distances and underestimate large sizes and distances. Poor subjects showed a consistent bias to overestimate all sizes and distances.

For good subjects, there was little or no difference between the stero and monocular presentation for either cone sizes or distances. For poor subjects, stereo was superior to monocular presentations for judging distance-to and distance between targets. There was no significant difference in judging sizes.

The effect of noise is primarily to eliminate those targets which subtend small visual angles. The presence of noise does not change the accuracy with which judgments are made of those targets which are seen.

There is no significant difference between monocular and stereo presentations at any of the noise levels. In the no-noise condition, monocular presentations yield a slightly greater group error than either of the stereo presentations as far as judging distance is concerned (there is no difference as far as judging size is concerned). This is largely because of the fact that in the no-noise condition a larger number of targets is seen in the monocular presentation than in the stereo presentations. The additional targets that are seen are the small, distant targets which are also those that are the source of the greatest mean error. Hence, seeing these additional targets has the effect of spuriously raising the group mean error for the monocular no-noise condition. These differences are eliminated, however, if one considers only the best subjects instead of the entire group.

There is no significant difference in performance or in accuracy of subjects in making judgments with either the Polaroid projection or the Trimension Reader method of presentation.

There were no significant differences in results as a function of the sex of the subject.

Those subjects who sat further from the projection screen saw somewhat fewer targets than those who sat closer, but the accuracy of judgment was the same for those targets that were seen.

Improvement can be made in good subjects by additional special training but it is more important to select good subjects in the first place by means of empiric tests. These tests should be realistic, since the results of the study show little general ability to make all kinds of judgments of a spatial nature. For example, those subjects who were the best in judging target size were seldom the same as those who were best at judging distance. Rank-order correlations between ability to judge cone size and ability to judge distance to targets were positive, but very low.

5. CONCLUSIONS

It is concluded that there is no significant difference between stereo and non-stereo presentations for good subjects when it comes to judging either size or distance of targets in pictorial representations.

It is concluded that reasonable results can be attained by good subjects after training. Typical values might be on the order of 3 or 4 inches of error for targets in the size range of 4 to 40 inches, 15 feet in judging distance over ranges up to 200 feet, and errors of approximately 3 feet in judging distance between targets over ranges of from 2 to 20 feet.

These are the results for any single subject, and represent absolute error. However, with good subjects, an error on the part of one subject (an overestimate, for instance) may be cancelled by an underestimate on the part of another subject making the same judgment. Under these circumstances, group mean relative errors may be less than one inch for target size, and 1 foot or less for distances over the same ranges as mentioned in the previous paragraph.

These are the results that are obtained in controlled situations where care was taken always to have congruence between the stereo pictures.

However, if stereo cameras are placed on a moving vehicle, there will be certain problems in achieving congruent images on the receiver whenever the vehicle is tilted along the transverse axis. With more than a few degrees of tilt, this may militate against stereoscopic fusion. Under these circumstances, degradation may be expected in a stereo presentation, but not in a monocular presentation.

Therefore, since similar results can be obtained with mono and with stereo presentations, and since there may be sources of degradation in the field that occur in stereo but not in mono, the conclusion is that stereo is not worth the additional cost and weight penalties, except solely as a redundant or back-up system.